APPENDIX 1

MIX DESIGN FOR M25 CONCRETE AS PER IS 10262:2009

Based on the test results obtained, the mix design for M25 concrete is done

STIPULATIONS FOR PROPORTIONING

a) Grade designation : M25

b) Type of cement : OPC 43 grade

c) Maximum nominal size of aggregate : 20 mm

d) Minimum cement content : 320 kg/m³

e) Maximum water-cement ratio : 0.45

f) Exposure condition : Normal

h) Maximum cement content : 450 kg/m³

i) Chemical admixture type : Superplasticizer
TEST DATA FOR MATERIALS

a) Cement used : OPC 43 grade

b) Specific gravity of cement : 3.15

c) Chemical admixture : Superplasticizer

d) Specific gravity of

1) Coarse aggregate : 2.78

2) Fine aggregate : 2.62

e) Water absorption :

1) Coarse aggregate : 0.5%

2) Fine aggregate : 1.0%

f) Free(surface) moisture :

1) Coarse aggregate : Nil

2) Fine aggregate : Nil

g) Sieve analysis :

Fine aggregate : Conforming to grading zone II of Table 4 of IS 383:1970
TARGET MEAN STRENGTH FOR MIX PROPORTIONING

\[ f_{\text{c}k} = f_{ck} + 1.65 \, s \]

where

\[ f_{\text{c}k} = \text{target average compressive strength at 28 days} \]

\[ f_{ck} = \text{characteristic compressive strength at 28 days} \]

\[ s = \text{standard deviation} \]

From Table 1 of IS 10262:2009, \( s = 4.0 \text{N/mm}^2 \)

Therefore, \( f_{\text{c}k} = 25 + (1.65 \times 4) = 31.6 \text{ N/mm}^2 \)

SELECTION OF WATER-CEMENT RATIO

From Table 5 of IS 456:2000,

Maximum water-cement ratio = 0.45

Hence adopt water-cement ratio as 0.45

SELECTION OF WATER CONTENT

From Table 2 of IS 10262:2009, for 20 mm nominal size aggregate and sand conforming to grading Zone II, Maximum water content /m³ of concrete = 186 litre.

The water content is for angular aggregate and for 25 to 50 mm slump range. For the desired workability, the required water content is
established by an increase by about 3 percent for every additional 25 mm slump.

Estimated water content for 75 mm slump

\[
= 186 + \frac{3}{100} \times 186 = 191.58 \text{ litres}
\]

**CALCULATION OF CEMENT CONTENT**

Water-cement ratio = 0.45

\[
\text{Cement content} = \frac{191.58}{0.45} = 425.73 \text{ Kg/m}^3.
\]

From Table 5 of IS 456:2000,

Maximum cement content for normal exposure condition

\[
= 320 \text{ Kg/m}^3 \ [425.73 \text{ Kg} / \text{ m}^3 > 320 \text{ Kg} / \text{ m}^3]. \text{ Hence OK.}
\]

**PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT**

From Table 3 of IS 10262:2009, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone II) for water - cement ratio of 0.50 = 0.62.

The present water - cement ratio is 0.45. Therefore volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water- cement ratio is lowered by 0.05, the proportion of volume of coarse aggregate is increased by 0.01.
Therefore, corrected proportion of volume of coarse aggregate for the water - cement ratio of $0.45 = 0.63$.

Volume of coarse aggregate = 0.63

Volume of fine aggregate = 1 - 0.63 = 0.37

**MIX CALCULATIONS**

The mix calculations per unit volume of concrete shall be as follows,

a) Volume of concrete = $1 \text{ m}^3$.

b) Volume of cement = \[
\frac{\text{Mass of cement}}{\text{Specific gravity of cement}} \times \frac{1}{1000}
\]

\[
= \frac{425.73}{3.15} \times \frac{1}{1000}
\]

\[
= 0.1351 \text{ m}^3
\]

c) Volume of water = \[
\frac{\text{Mass of water}}{\text{Specific gravity of water}} \times \frac{1}{1000}
\]

\[
= \frac{191.58}{1} \times \frac{1}{1000} = 0.1915 \text{ m}^3
\]

d) Volume of chemical admixture
\[
\text{Mass of chemical admixture} \times \frac{1}{\text{Specific gravity of chemical mixture}} \times \frac{1}{1000}
\]

\[
= \frac{3.405}{1.20} \times \frac{1}{1000}
\]

\[
= 0.0028 \text{ m}^3
\]

e) Volume of all aggregates = \( a - (b + c + d) \)

\[
= 1 - (0.1351 + 0.1915 + 0.0028)
\]

\[
= 0.670 \text{m}^3
\]

f) Mass of coarse aggregate = \([e \times \text{volume of C.A} \times \text{specific gravity of C.A} \times 1000]\)

\[
= (0.670 \times 0.63 \times 2.78 \times 1000) = 1174.42 \text{ m}^3
\]

g) Mass of Fine aggregate = \([e \times \text{volume of F.A} \times \text{specific gravity of F.A} \times 1000]\)

\[
= (0.670 \times 0.37 \times 2.62 \times 1000) = 649.498 \text{ m}^3
\]
MIX PROPORTION

The mix proportion for M25 grade concrete arrived is shown in Table A1.1.

Table A1.1  Mix proportion for M25 grade concrete

<table>
<thead>
<tr>
<th>Details</th>
<th>Cement</th>
<th>FA</th>
<th>CA</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity(kg/m³)</td>
<td>425.73</td>
<td>649.498</td>
<td>1174.42</td>
<td>191.58</td>
</tr>
<tr>
<td>Proportion</td>
<td>1</td>
<td>1.52</td>
<td>2.75</td>
<td>0.45</td>
</tr>
</tbody>
</table>
APPENDIX 2

Design of Beam

Basic Data:

Grade of Concrete : M25
Grade of steel : Fe 415
Length of Beam : 2.10 m
Effective span Length : 1.80 m
Breadth of beam : 150 mm
Depth of Beam : 250 mm
Loading Method : Two point Load
                     (Equal Distance (L/3))
End condition : Simply Supported Beam

\[ f_{ck} = 25 \text{ N/mm}^2 \]

\[ f_y = 415 \text{ N/mm}^2 \]

\[ A_{st} = 4 \times 3.14 \times 10^3 / 4 = 452.16 \text{ mm}^2 = 314 \text{ mm}^2 \]
Clear cover = 25 mm

Effective depth = 250-25-(12/6) = 219 mm = 220 mm

Limiting depth of N-A

\[ x_{u, \text{lim}} = 0.48 \]  [for \( F_y = 415 \text{ N/mm}^2 \), As per IS 456:2000]

i.e., \[ \frac{x_{u, \text{max}}}{d} = 0.48 \], i.e., \( x_{u, \text{max}} = 0.48 \times 220 = 105.6 \text{ mm} \)

Actual depth of N-A

\[ \frac{x_u}{d} = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b d}, \text{ i.e., } x_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b} = \frac{0.87 \times 415 \times 453}{0.36 \times 25 \times 150} = 83.98 \text{ mm} < 105.6 \text{ mm} \text{ i.e., } x_u < x_{u, \text{lim}} \]

Minimum \( A_u \) required = 0.12\% of total CSA

\[ = (0.12/100) \times 250 \times 150 = 45 \text{ mm}^2 \]

As \( x_u < x_{u, \text{lim}} \),

Moment of resistance is given by

\[ M_u = 0.87 f_y A_{st} d \left[1 - \frac{A_{st} f_y}{b d f_{ck}}\right] \]

\[ M_u = 0.87 \times 415 \times 314 \times 220 \left[1 - \frac{314 \times 415}{150 \times 220 \times 25}\right] \]

\[ = 21 \times 10^6 \text{ N-mm} = 21 \text{ kN-m} \]
The limiting moment of resistance is given by

\[ M_{u,\text{lim}} = 0.36 \frac{x_{u,\text{max}}}{d} \left[ 1 - 0.42 \frac{x_{u,\text{max}}}{d} \right] b d^2 f_{ck} \]

\[ M_{u,\text{lim}} = 0.36 \times 0.48 \left[ 1 - 0.42 \times 0.48 \right] x 150 \times 220^2 \times 25 \]
\[ = 25 \times 10^6 \text{ N-mm} = 25.04 \text{ kN-m} \]

Since \( M_u < M_{u,\text{lim}} \), the mode of failure is due to flexure.

Increasing the shear capacity of the beam,

\[ M = Wl/3 \text{ i.e., } W = 3M/l = 3 \times 21/1.8 = 35 \text{ kN} \]

Jack load (2W) = 70 kN

**Design for Shear Resistance**

Shear force, \( V = 35 \text{ kN} \)

\[ \frac{100 A_s}{b d} = \frac{100 \times 314}{150 \times 220} = 0.952 \]

From Table 19 of IS 456-2000,

For \( p_t = 0.952 \) and M 25 grade concrete,

Design shear strength of concrete, \( \tau_c = 0.63 \text{ N/mm}^2 \).
From Table 20 of IS 456-2000,

Maximum shear stress, \( \tau_{c \text{ max}} = 3.1 \, \text{N/mm}^2 \).

Nominal shear stress, \( \tau_v = \frac{V_u}{b \, d} = \frac{35 \times 1000}{150 \times 220} \)

\[ = 1.06 \, \text{N/mm}^2 < 3.1 \, \text{N/mm}^2 \text{ i.e., } \tau_v < \tau_{c \text{ max}} \]

\( V_{us} = (V_u - \tau_c \, b \, d) = (\tau_v - \tau_c) \, b \, d \)

\[ = (1.06 - 0.63) \times 150 \times 220 = 14.2 \, \text{kN} \]

The strength of shear reinforcement (for vertical stirrups)

Shear reinforcement, \( V_{us} = \frac{0.87 \, f_y \, A_{sv} \, d}{S_v} \)

Total cross-sectional area of 2-legged 8 mm dia. stirrup legs

\( A_{sv} = 2 \times 3.14 \times 8^2/4 = 100.48 \, \text{mm} = 101 \, \text{mm}^2 \)

Hence, \( S_v = \frac{0.87 \, f_y \, A_{sv} \, d}{V_{us}} \)

\[ = \frac{0.87 \times 415 \times 101 \times 220}{14.2 \times 10^3} = 564.96 \, \text{mm} = 565 \, \text{mm} \]

Providing maximum spacing of shear reinforcement as per IS 456-2000 [Clause 26.5.1.5]
(i) Shall not exceed 0.75 \(d\) for vertical stirrups \((0.75 \times 220 = 165\) mm)

(ii) Spacing shall not exceed 300 mm

Hence 8 mm dia, 2 legged vertical stirrups are provided at a spacing of 100 mm.

The beam withstands up to \(V_u = V_c + V_s\)

\[
V_s = \frac{0.87 f_y A_{sv} d}{S_v} = \frac{0.87 \times 415 \times 101 \times 220}{100}
\]

\[
= 80,225 \text{ N} = 80.225 \text{ kN}
\]

\[V_c = 0.75 \times 150 \times 220 = 24,750 \text{ N} = 24.75 \text{ kN}\]

Therefore, \(V_u = V_c + V_s = 24.75 + 80.225\)

\[
= 104.975 \text{ kN} > 70 \text{ kN}
\]

Hence the failure is due to flexure mode.
APPENDIX 3

Modelling of frames

General

A single bay two storey structure was analyzed and designed for gravity loading. The structure was modeled for experimental investigation by scaling down the geometric properties of the prototype using the laws of similitude.

Modeling of frame

The test models were fabricated to a reduced scale satisfying the laws of similitude. The scale factor was based on the capacity and dimension of the reaction frame and test floor.

Scale factors

The scale factors adopted for the frame specimens are tabulated in Table A3.1.
Table A3.1  Scale factors adopted

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Variables considered</th>
<th>Scale factor notation</th>
<th>Scale factor adopted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Length</td>
<td>$S_L$</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Time</td>
<td>$\sqrt{S_L}$</td>
<td>1.73</td>
</tr>
<tr>
<td>3</td>
<td>Mass and Load</td>
<td>$S_E, S_L^2$</td>
<td>2.99</td>
</tr>
<tr>
<td>4</td>
<td>Frequency</td>
<td>$1/\sqrt{S_L}$</td>
<td>0.58</td>
</tr>
<tr>
<td>5</td>
<td>Modulus of Elasticity</td>
<td>$S_E$</td>
<td>1</td>
</tr>
</tbody>
</table>

The dimensions and reinforcement details of the model frame are listed in Table A3.2.

Table A3.2  Dimensions and reinforcement details of 2-D model frame

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Item</th>
<th>Size (m)</th>
<th>Reinforcements adopted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Beam</td>
<td>1.0 x 0.1 x 0.1</td>
<td>Main: 4 nos. of 10 mm dia. bars at top &amp; bottom,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stirrups: 8 mm dia. bars at 100 mm c/c spacing</td>
</tr>
<tr>
<td>2</td>
<td>Columns</td>
<td>1.1 x 0.1 x 0.1</td>
<td>Main: 4 nos. of 12 mm dia. bars</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stirrups: 8 mm dia. bars at 100 mm c/c spacing</td>
</tr>
<tr>
<td>3</td>
<td>Raft slab</td>
<td>1.5 x 1.0 x 0.1</td>
<td>10 mm dia. bars at 100 mm c/c in both directions in two layers</td>
</tr>
</tbody>
</table>